MIXING LIQUIDS AND ENTRAINMENT MIXING OF VAPOR INTO LIQUIDS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. provisional application No. 60/196,999, filed Apr. 13, 2000.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to a mixing apparatus and more particularly to a magnetically driven rotary mixer for the mixing of liquids and for the rapid mixing entrainment of vapor into liquids.

2. Description of the Background

Mixing of fluids is an integral component in innumerable operations in chemical processing, both for industrial and research applications. Countless instances require mixing of reactants in large-scale stirred chemical reactors in order to optimize blend times and minimize power consumption. On smaller scales in scientific instrumentation, many applications incorporate a fluid mixing operation. These include, for example, measurement apparatus for vapor liquid equilibrium, and for liquid-phase kinetics measurements. Moreover, numerous analytical procedures require the mixing of reagents and reactants in a controlled, closed environment to complete a chemical measurement.

Many liquid mixing operations can be accomplished with devices that provide gentle blending, with little or no entrainment of the vapor that exists above the liquid. Indeed, this may be optimal for some mixing operations. In these instances, a wide variety of magnetic stirring rotors (generally called stirbars) are commercially available in many different sizes and shapes.

For operations that specifically require both the mixing of the liquid and the entrainment of vapor into the liquid, there are limited choices. A search of the patent and open literature did not reveal any commercially available magnetic stirrers that will entrain vapor and maintain a stable rotary motion. The only readily available stirrers of which applicants are aware require an external shaft to drive a mixing rotor. Such devices include the Rushton turbine (which employs six flat turbine blades mounted about a central shaft-driven disk), and modifications (such as the Chemineer CD-6, CD-6/HE 3, etc.) in which the blades have varying degrees of symmetric and asymmetric concavity.

Common problems with shaft mounting designs include inevitable wear and deterioration of the shaft seal, and inhomogeniety due to unswept liquid volume that remains in the region of the seal. These problems make an external shaft device unsuitable for a vapor/liquid equilibrium apparatus or for small-scale chemical reactors. Another common problem with the small chemical mixers driven by external shaft devices is the presence of volume element regions of different surface to volume ratios as compared to the main body of the containment vessel. This same problem occurs when liquid or vapor-circulating pumps are used to provide mixing in many of the existing apparatus for vapor liquid equilibrium.

Accordingly, there is a need for a magnetically driven fluid mixer suitable for mixing the liquid phase and rapidly entraining vapor into the liquid. The present invention satisfies these needs, as well as others, and generally overcomes the deficiencies found in the background art.

SUMMARY OF THE INVENTION

The present invention uses a magnetically driven rotary mixer which mixes liquids and entrains vapor into liquids. In general terms, the invention uses a vertical rotor consisting of a hollow tube having external screw threads and at least one sidewall aperture or hole, the tube being mounted centrally on a base assembly. The rotor and base rest within a containment vessel. A magnetic mixing motor is located beneath the containment vessel to provide a magnetic flux coupling drive to the base and rotor.

More specifically, the tube has a longitudinal bore extending from an open top end of the tube to a closed bottom, the closed bottom end forming a floor at the termination of the longitudinal bore. By way of example and not of limitation, at least one uniform helix in the form an external screw thread is formed on the outside axial surface of the tube in a right side configuration, i.e., in elevation view of the tube in upright position, the external threads are higher on the right side of the tube than on the left side. At least one hole pierces the tube's sidewall at a point above the floor which is defined by the closed bottom end of the longitudinal bore. The bottom end of the tube is fixedly attached or integrally molded with a base assembly comprising a disk and a linear magnet. The disk has a flat bottom surface. The stirbar extends radially from the perimeter of the tube along the top of the disk, the stirbar being either fixedly attached to or integrally molded with the disk. The rotational axes of both the rotor and base are vertically aligned and are preferably perpendicular to the flat bottom surface of the disk. A magnet preferably comprising strontium carbonate—iron oxide, is enclosed within the disk. The disk rests on the floor of a containment vessel capable of containing the tube and base. A magnetic stirring motor is disposed beneath the containment vessel and is coupled by magnetic flux with the base magnet.

As the magnetic stirring motor operates, the tube and base of the invention rotate in a counter-clockwise direction (as observed from a plan view) within the containment vessel, permitting robust mixing of liquid within the mixing containment vessel. As mixing proceeds, liquid is urged away from the rotor, forming a vortex. The speed of the mixing motor is controlled such that the lowest surface of the vortex forms at approximately the same plane as the sidewall hole or aperture. At the same time, vapor within the containment vessel is drawn down by the rotating action of the helix and is robustly mixed with liquid. The vapor is drawn through the hole **108** in the sidewall of tube **102**, and the vapor rises through the liquid in the longitudinal bore, thus promoting entrainment of the vapor into the liquid.

The present invention may therefore comprise an apparatus for mixing liquid and for entrainment mixing of vapors in liquid which comprises a tube having an open top end and a longitudinal bore extending into the tube from an open top end to a closed bottom end, the closed bottom end forming a floor within the longitudinal bore, the tube also having an exterior bottom end, the tube further having an exterior axial surface between the open top end and the exterior bottom end, the exterior axial surface having at least one helix in the form an external screw thread, the tube also having a sidewall between the exterior axial surface and the longitudinal bore, the sidewall also defining at least one aperture for circulation of vapor.

The present invention may further comprise an apparatus for mixing liquid and for entrainment mixing of vapors in liquid comprising a tube having an open top end and a longitudinal bore extending into the tube from the open top end to a closed bottom end, the closed bottom end forming a floor within the longitudinal bore, the tube also having an exterior bottom end, the tube further having an exterior axial surface between an open top end and an exterior bottom end,